



Evaluation of Fatigue Life for a Large Bus by using the Virtual Test Model (VTM)

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Hyundai Motor Company



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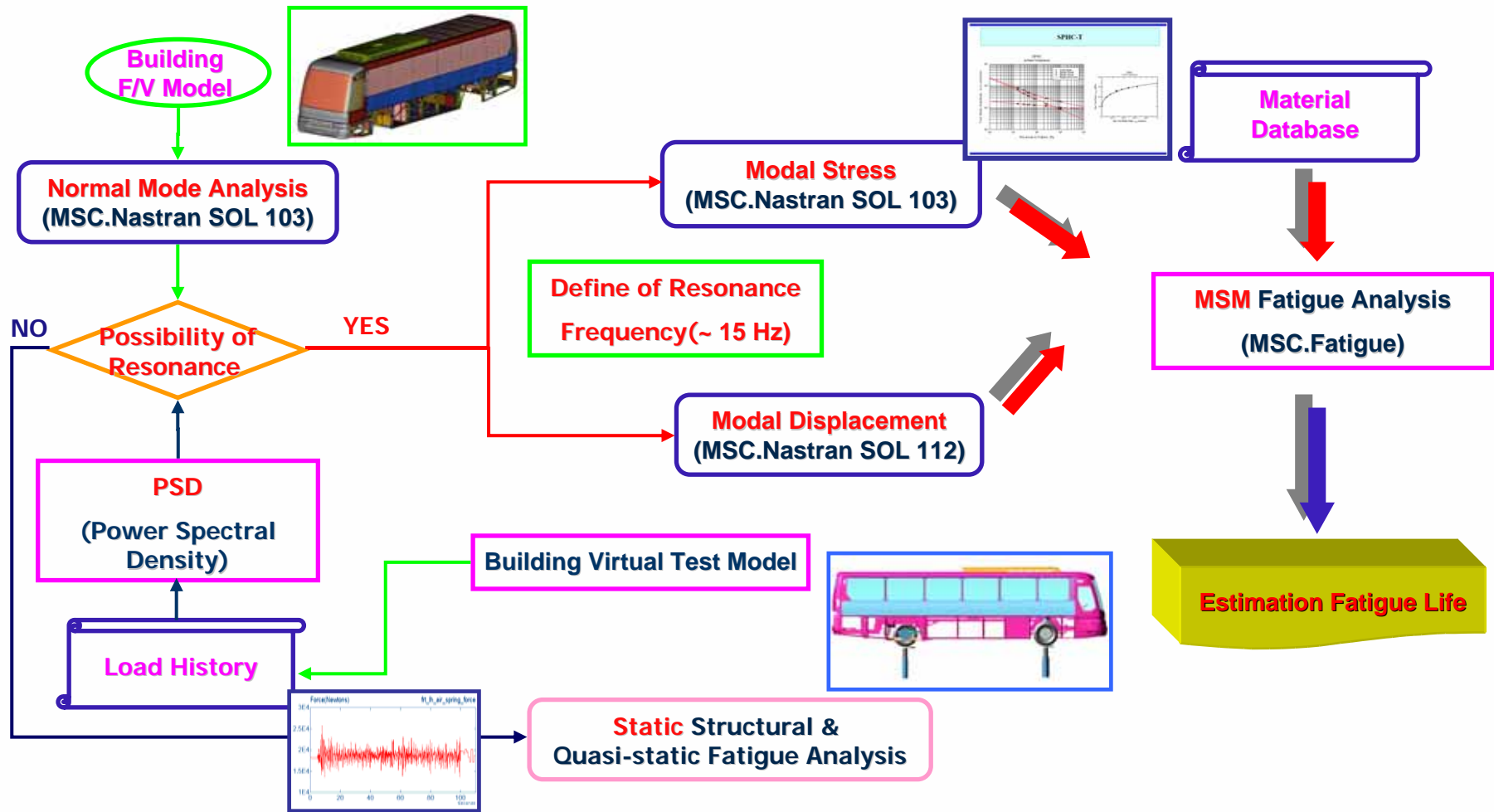


1. **The Process of Durability Analysis using Modal Superposition Method (MSM)**
2. **The Construction of a Full Vehicle Model**
3. **The Calculation of Load History using the Virtual Test Model**
4. **The Test of Material Property**
5. **The Results of MSM Durability Analysis**
6. **Conclusion**



The process of durability analysis using MSM

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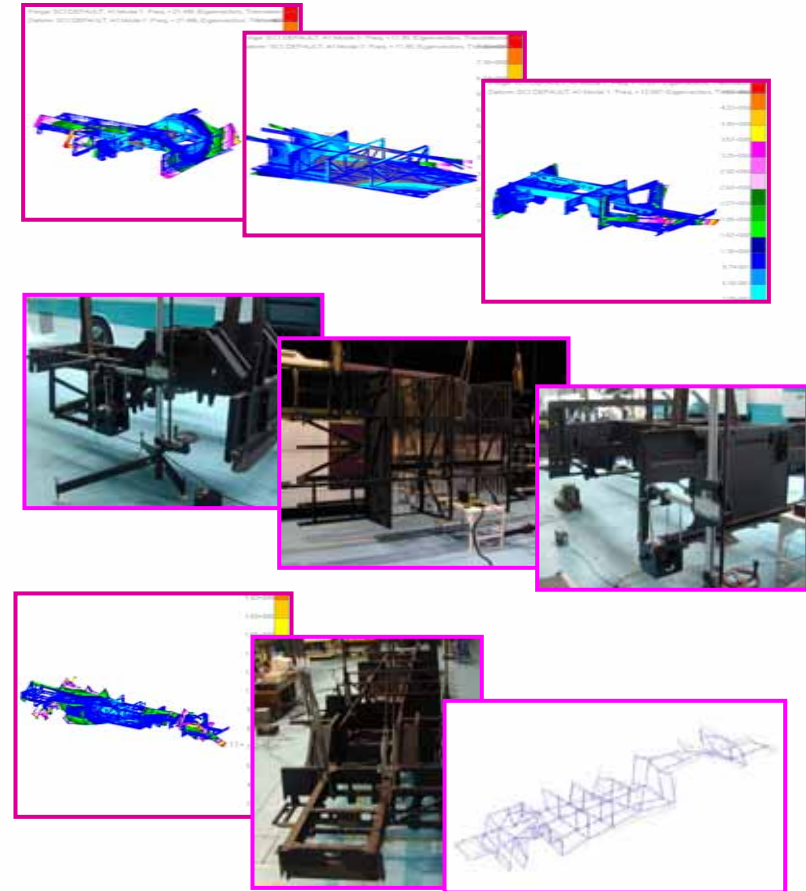
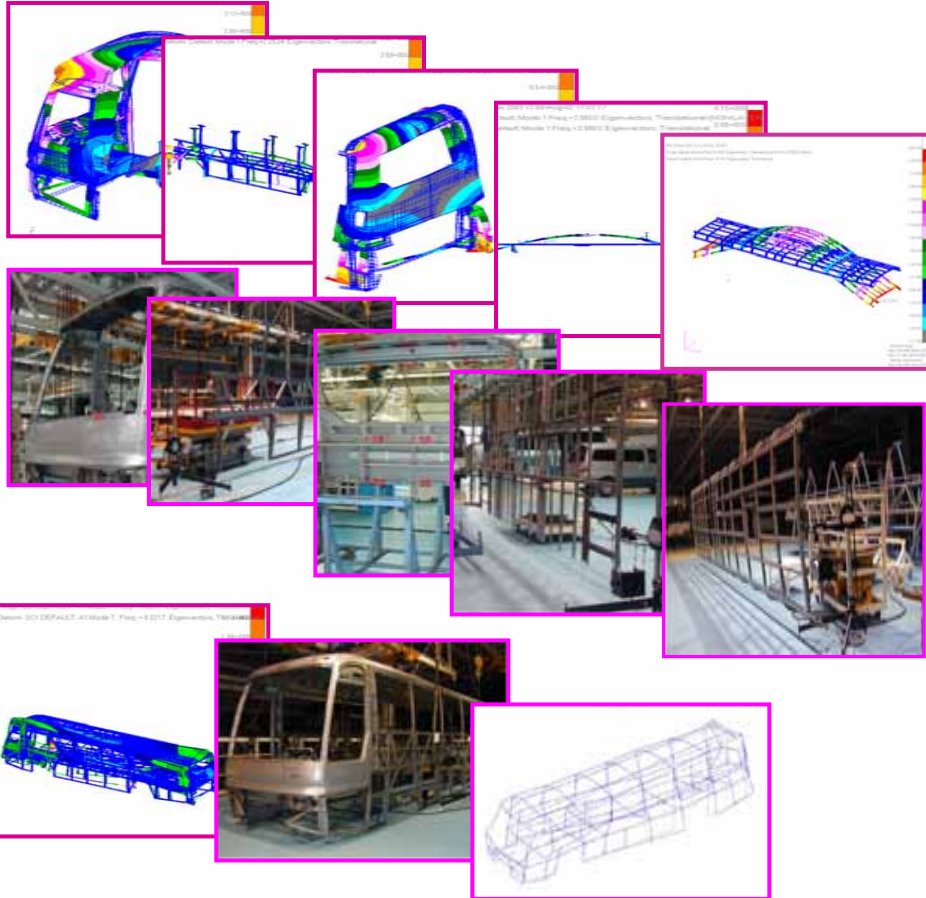


Building a B.I.W Model

► Verification of FE Models by Comparing with Modal Test Results of Sub-assemblies



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PRODUCT DEVELOPMENT CONFERENCE

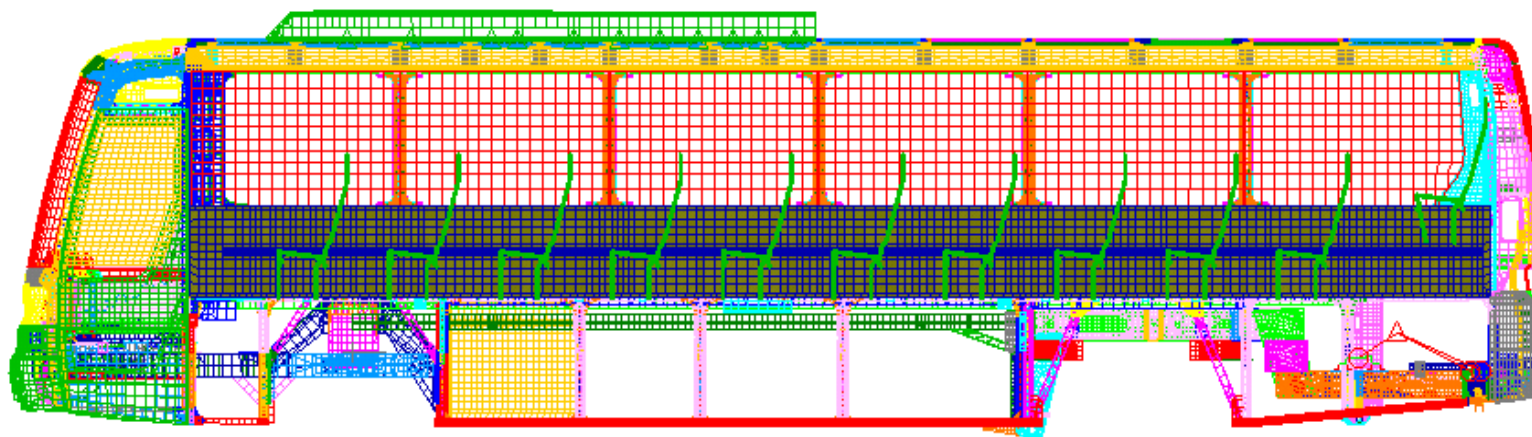


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Building a Trimmed Body Model

- Elements: 284,165 EA
- Grids : 292,528 EA
- MPCs : 16,474 EA
- Physical Properties : 512 EA
- Material Properties : 8 EA

ITEM	Weight
Engine+TM	1600 Kg
Aircon	250 Kg
Seats	685 Kg
Total Trim	3700 Kg
B.I.W	3600 Kg

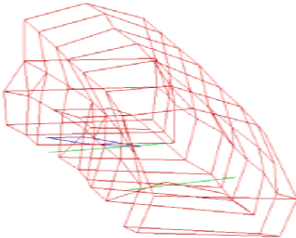
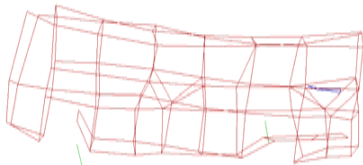
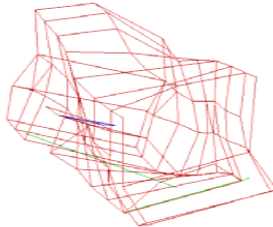
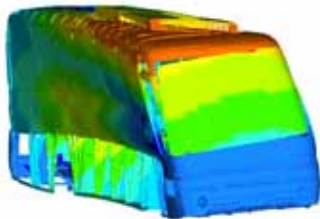
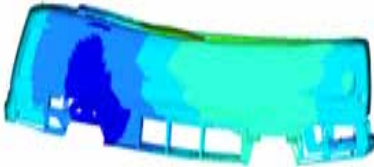
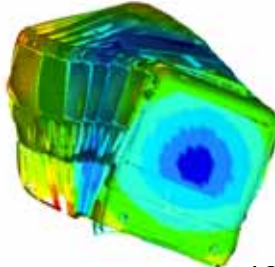




Mode Comparison between Analysis and Test



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	Shear Mode	Bending Mode	Torsion Mode
Test	 <p>9.6 Hz</p>	 <p>11.6 Hz</p>	 <p>12.6 Hz</p>
Analysis	 <p>9.4 Hz</p>	 <p>11.5 Hz</p>	 <p>12.9 Hz</p>

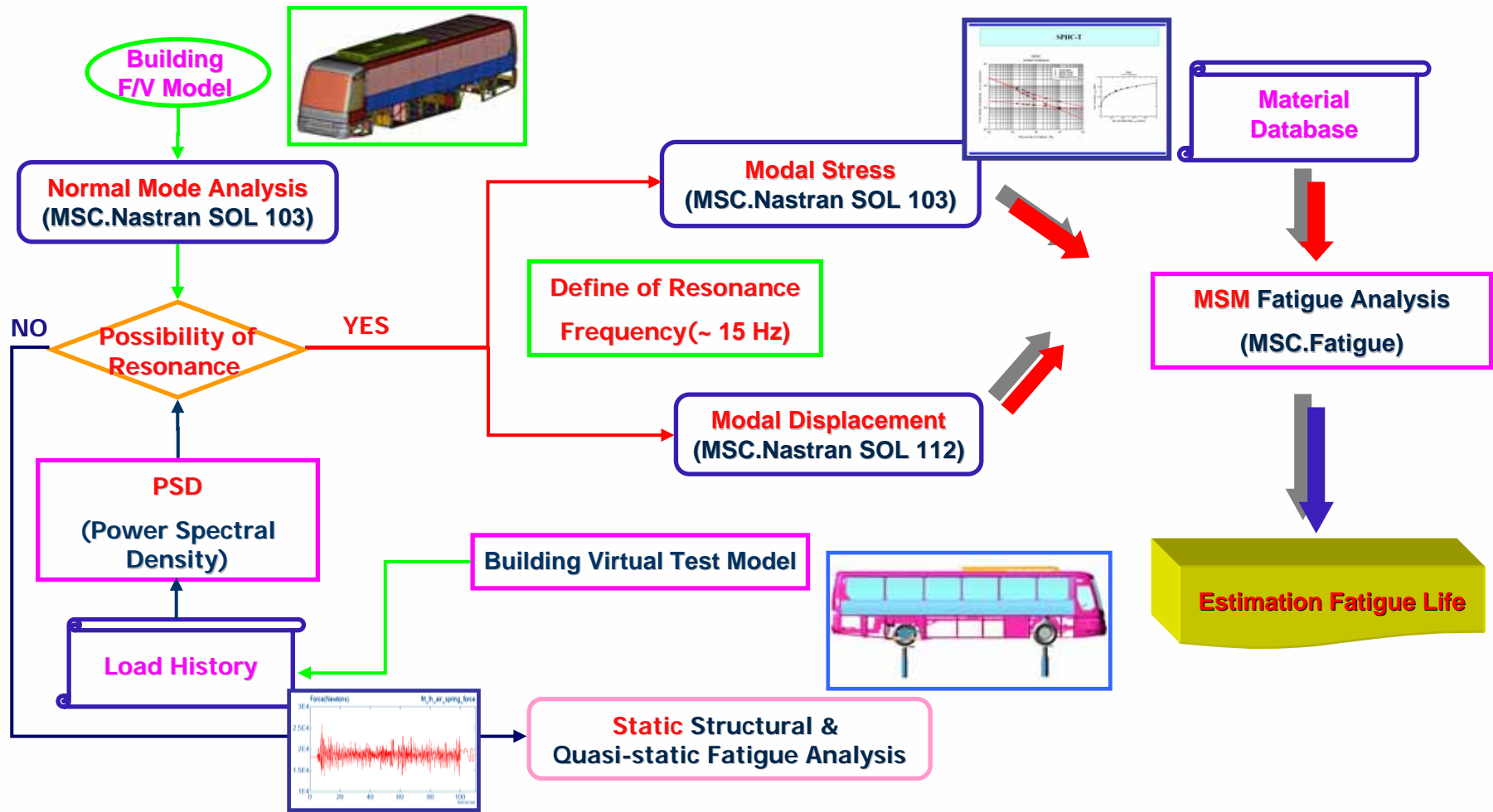
★ Running Mode Test

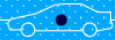
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The process of durability analysis using MSM

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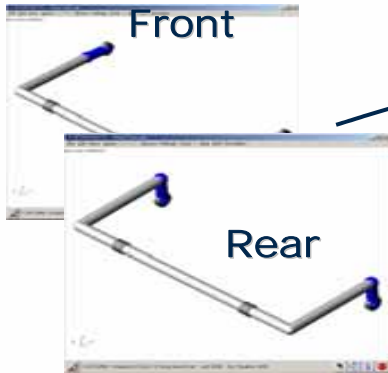




The Construction of Virtual Test Model



■ Front/Rear ARB Subsystem



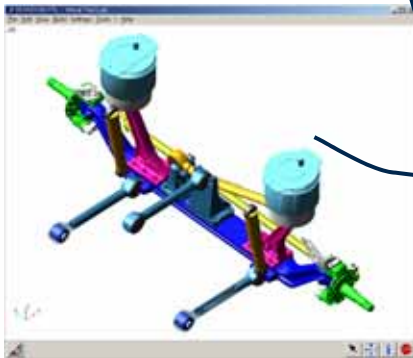
■ Trimmed Body Model



■ Steering Subsystem



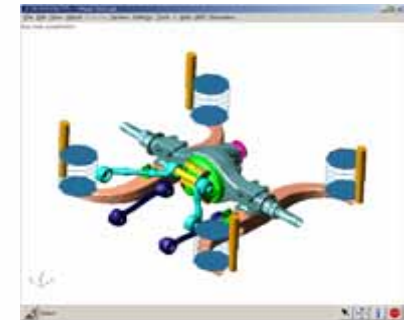
■ Front Suspension Subsystem



■ 4 Post Test Rig



■ Rear Suspension Subsystem



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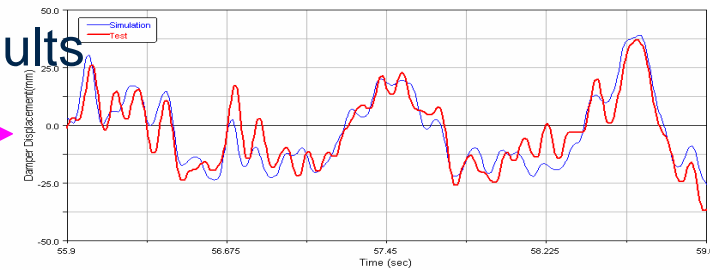
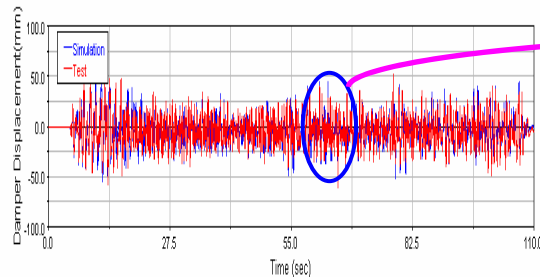
The Correlation of Virtual Test Model



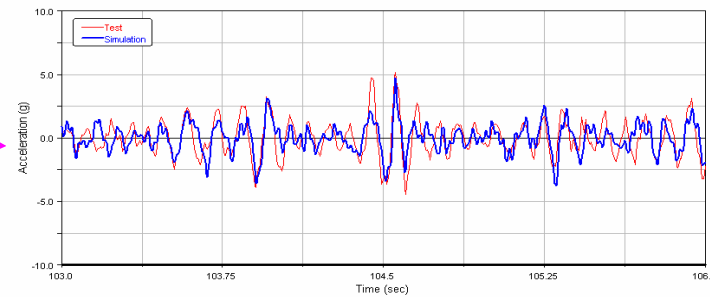
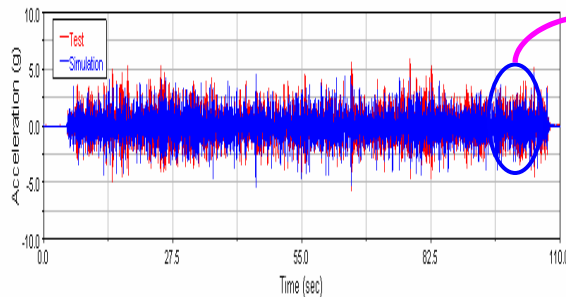
Static Analysis

ITEM	Axle Weight		
	C.V.W	Simulation	Error
Front	4,512 kg	4,482 kg	-30 kg
(%)	36.3%	35.70%	-0.7%
Rear	7,926 kg	7,942 kg	16 kg
(%)	63.7%	64.30%	0.2%
TOTAL	12,438 kg	12,424 kg	0.3%

Comparison of Test & Simulation Results



Front Damper Displacement LH

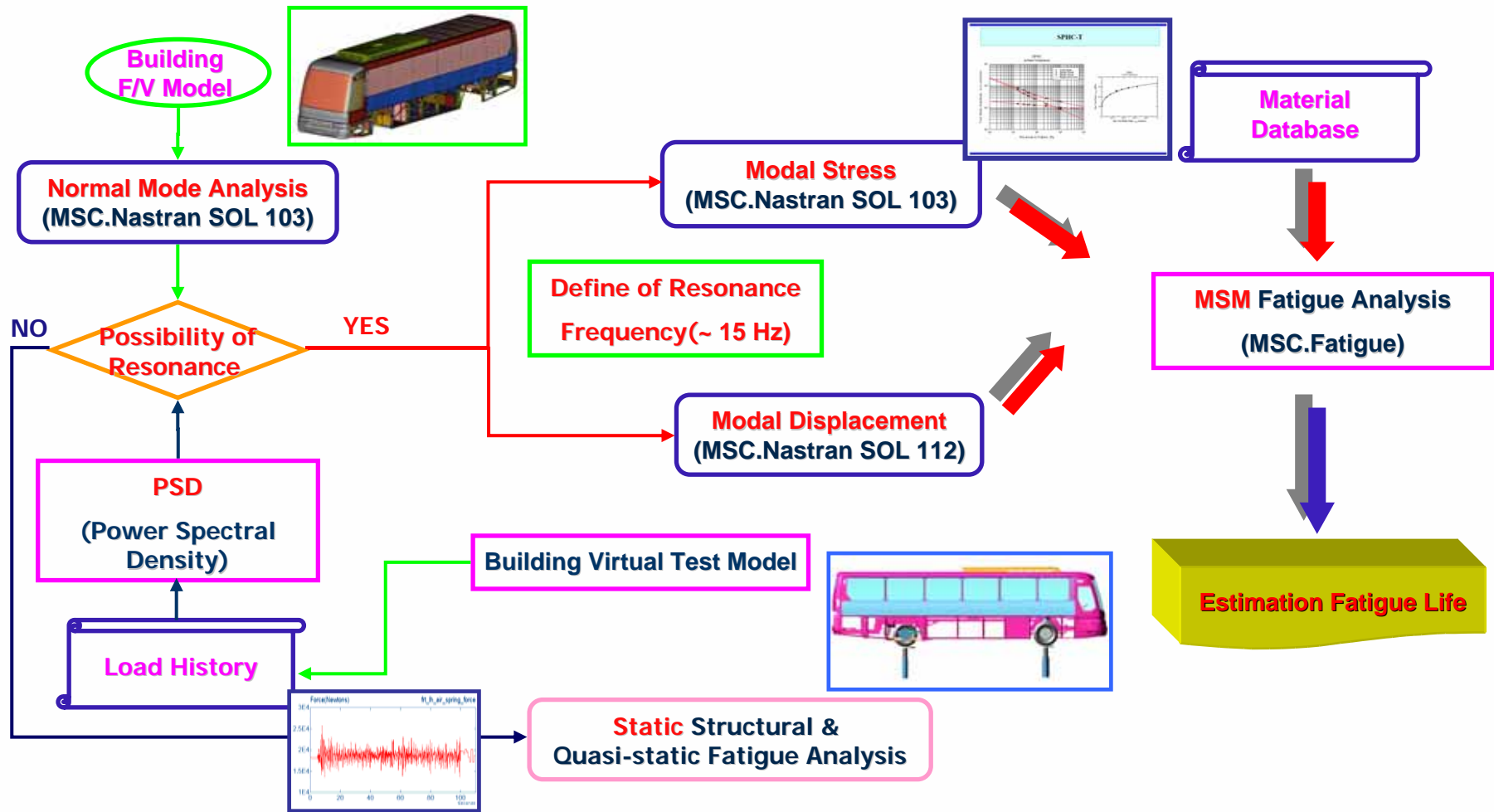


Front Axle Acceleration LH



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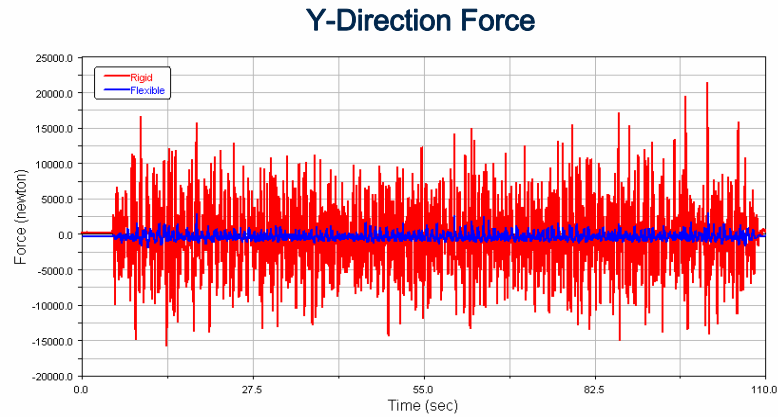
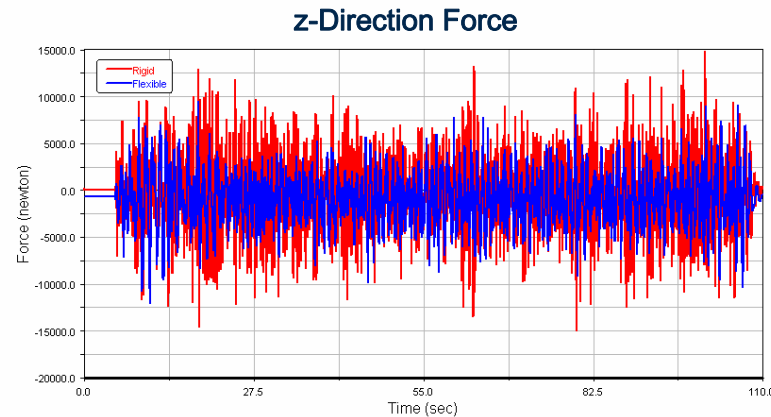


The Calculation of Load History using the VTM

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- Various Combination of dynamic models and Body FE Models for load history

* Comparison of Flexible Body + Flexible Suspension & Rigid Body + Rigid Suspension



Front Lateral Rod Body Mounting Bush Force –LH

- ▶ R/B+R/S Overestimates Load History due to unrealistic strong rigidity
- ▶ F/B+F/S seems predicts correct load history, but takes too much computing resources.



The Calculation of Load History using the VTM

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* The Comparison of Load History for R/B+F/S & F/B+R/S & F/B+F/S

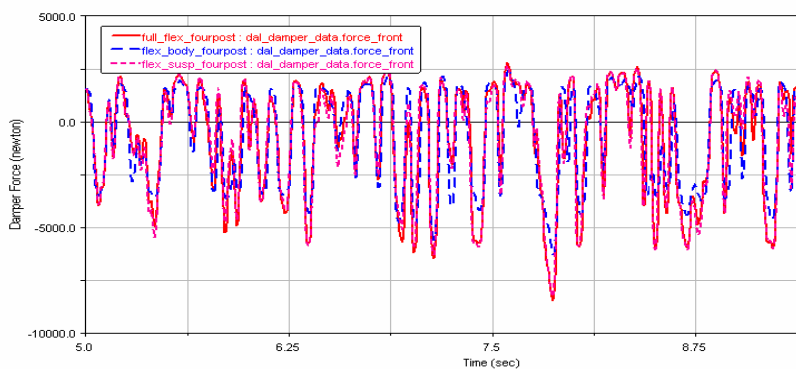
Damper Force RMS Results

	RMS		
	R/B+F/S	F/B+R/S	F/B+F/S
Front LH Damper	2928.1	2959.61	2919.61
Rear LH Front Damper	1636.83	1710.54	1641.1
Rear LH Rear Damper	1646.56	1726.75	1634.31

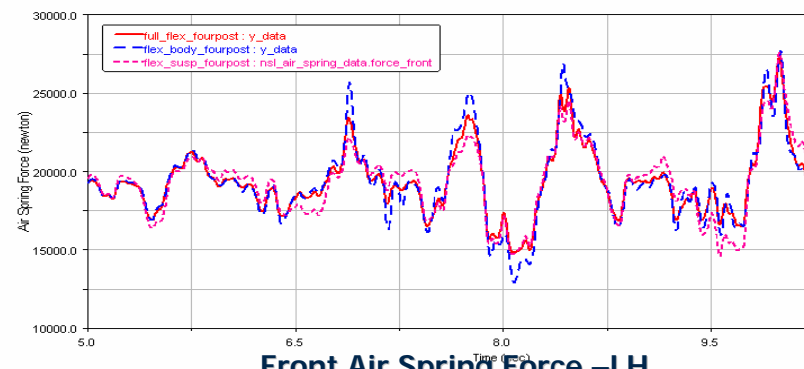
Air Spring Force RMS Results

	RMS		
	R/B+F/S	F/B+R/S	F/B+F/S
Front LH Air Spring	19443.22	19378.4	19447.28
Rear LH Frt Air Spring	16567.87	16236.53	16203.79
Rear LH RR Air Spring	1646.56	1726.75	1634.31

Difference of RMS for F/B+F/S & R/B+F/S: 5 %



Front Damper Force -LH



Front Air Spring Force -LH

- ▶ R/B+F/S Model Predicts Load History most closely to F/B+F/S Model with moderate computing resources

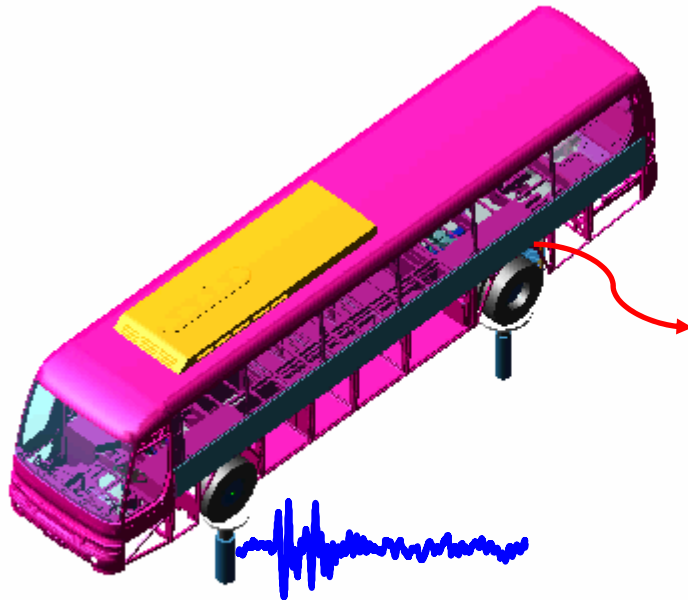
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The Calculation of Load History using the R/Body+ F/Suspension

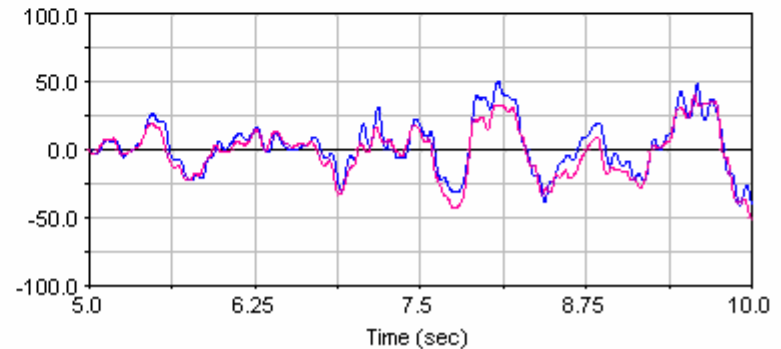
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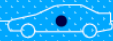
aa_fourpost Time= 5,0550 Frame=1013



Actuating load
for Test Rig

aa_fourpost Time= 5,0550 Frame=1013



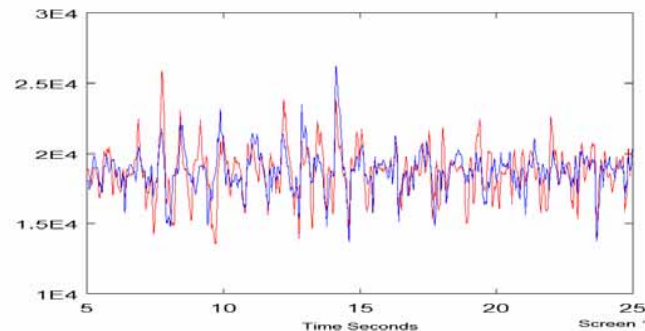
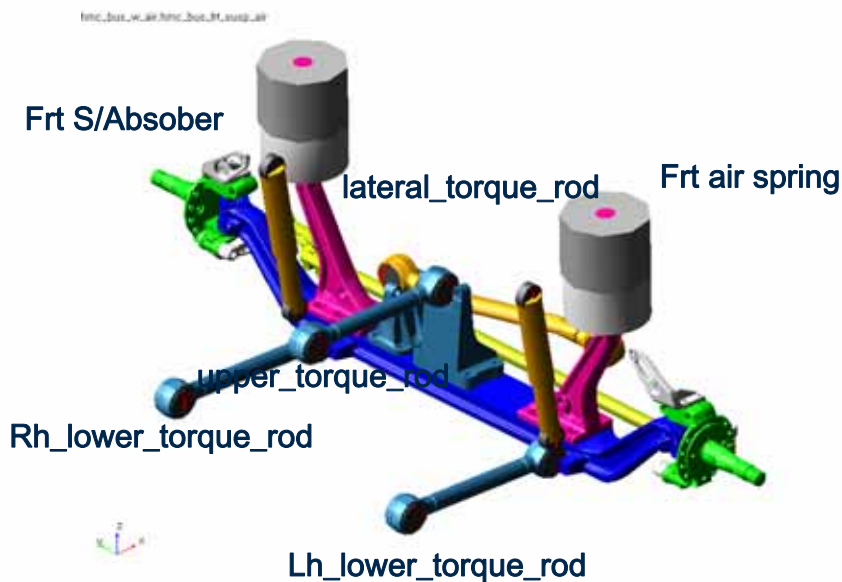


Load Input positions for Fatigue Analysis

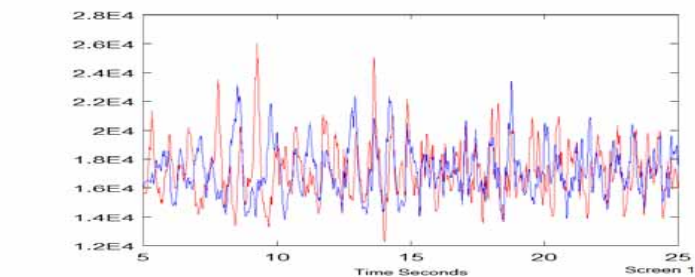


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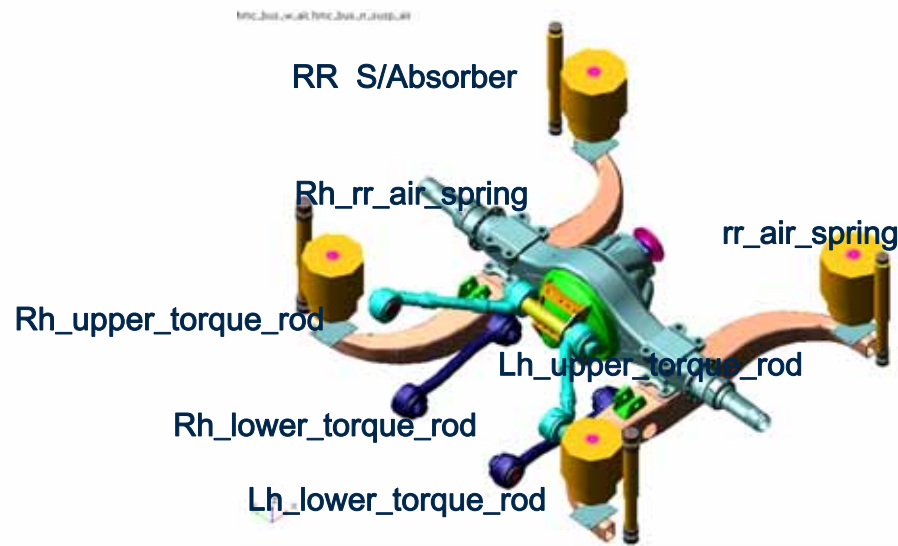
(Hard Points : 36 CHs)



Frt air spring



RR RR air spring

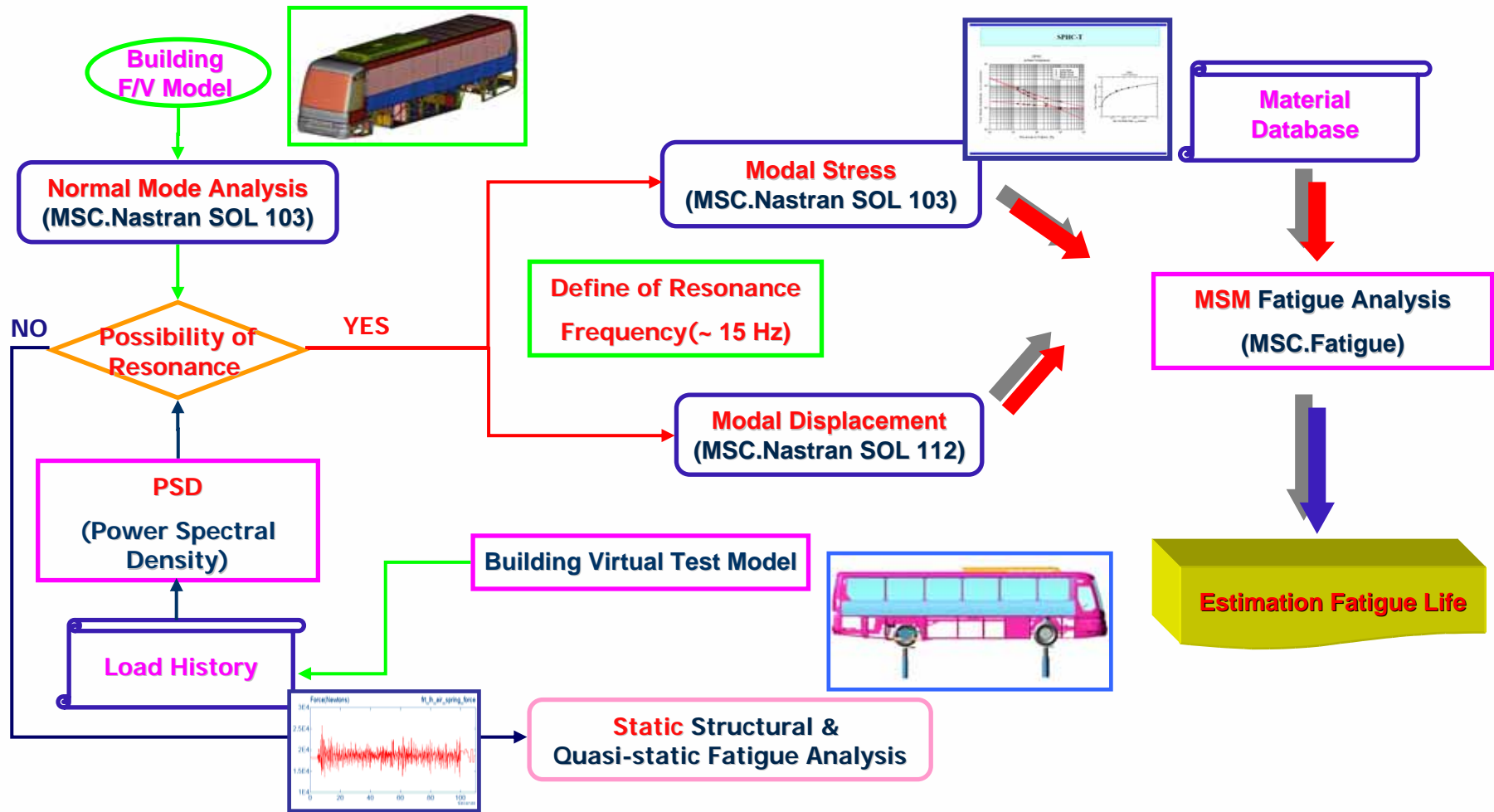


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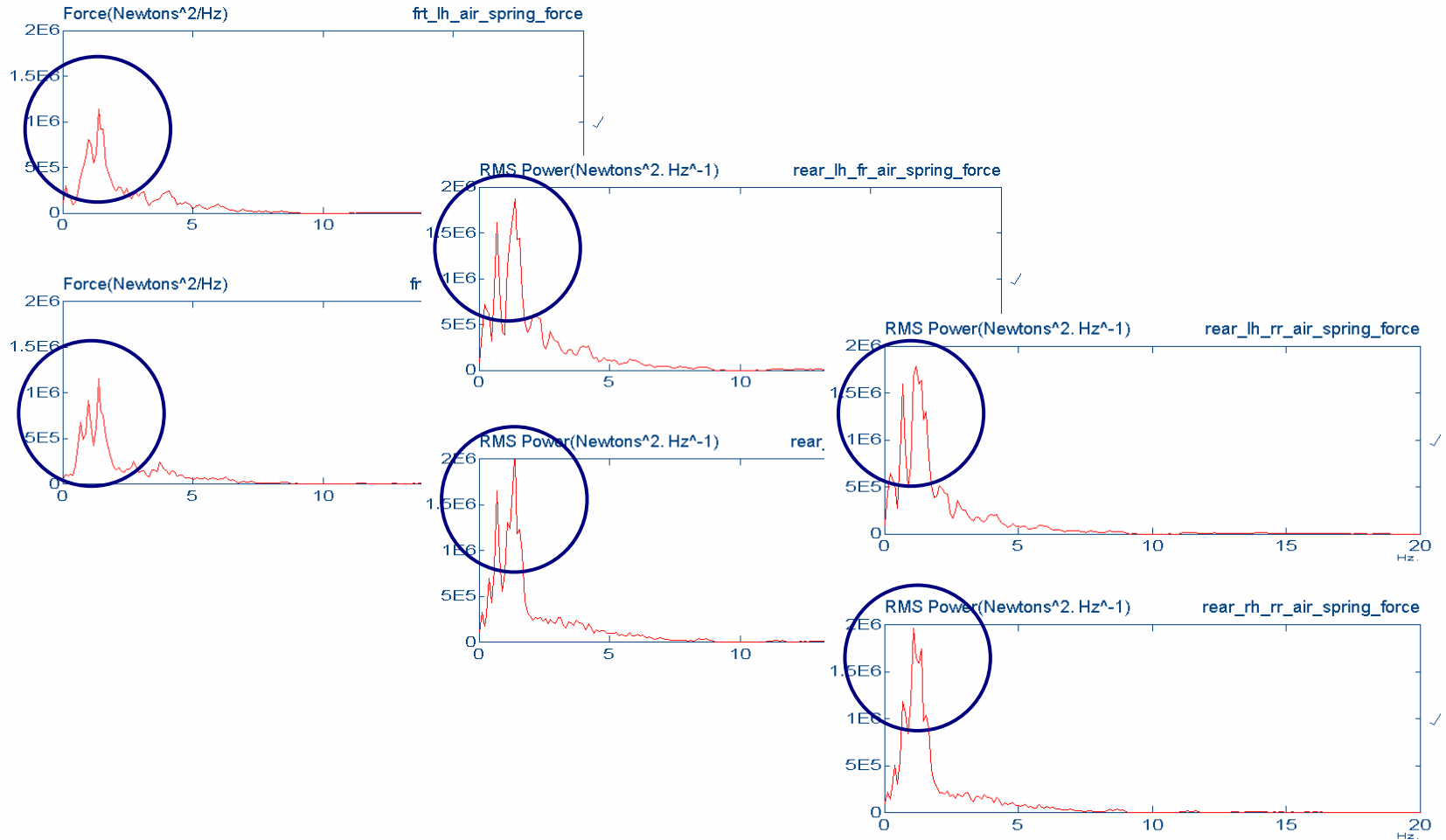
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PSD Analysis of the Input Load History

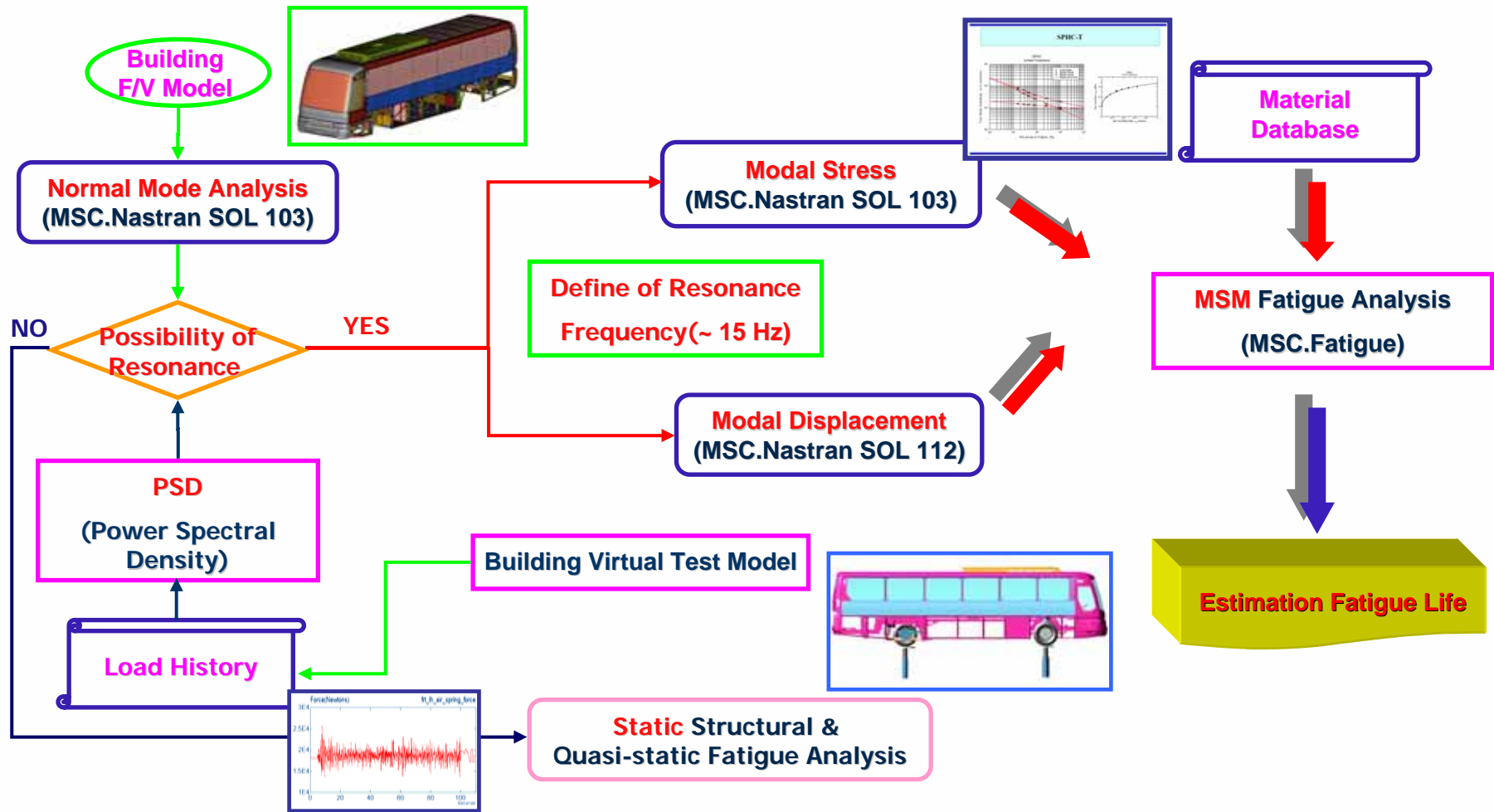


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The process of durability analysis using MSM

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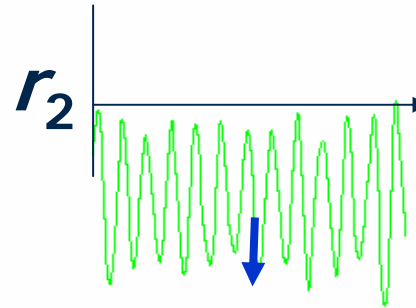
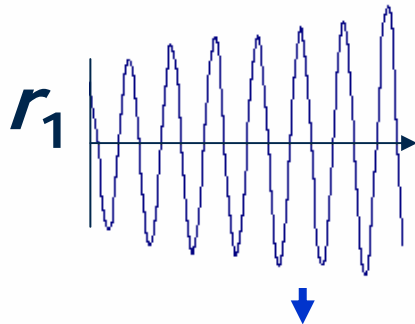
Modal Superposition



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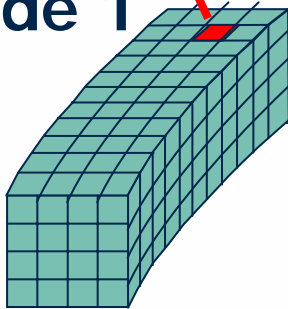
- repeat for each node/element

Modal Responses

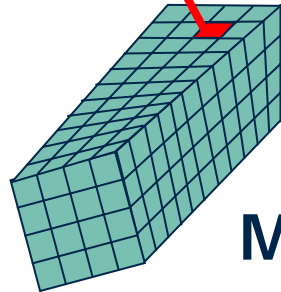


$$\phi_{1A}^* r_1(t) + \phi_{2A}^* r_2(t) + \dots = \sigma_A(t)$$

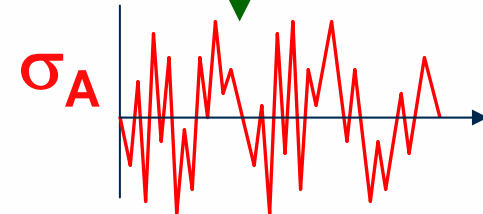
Mode 1



Mode 2



Local Stress Histories



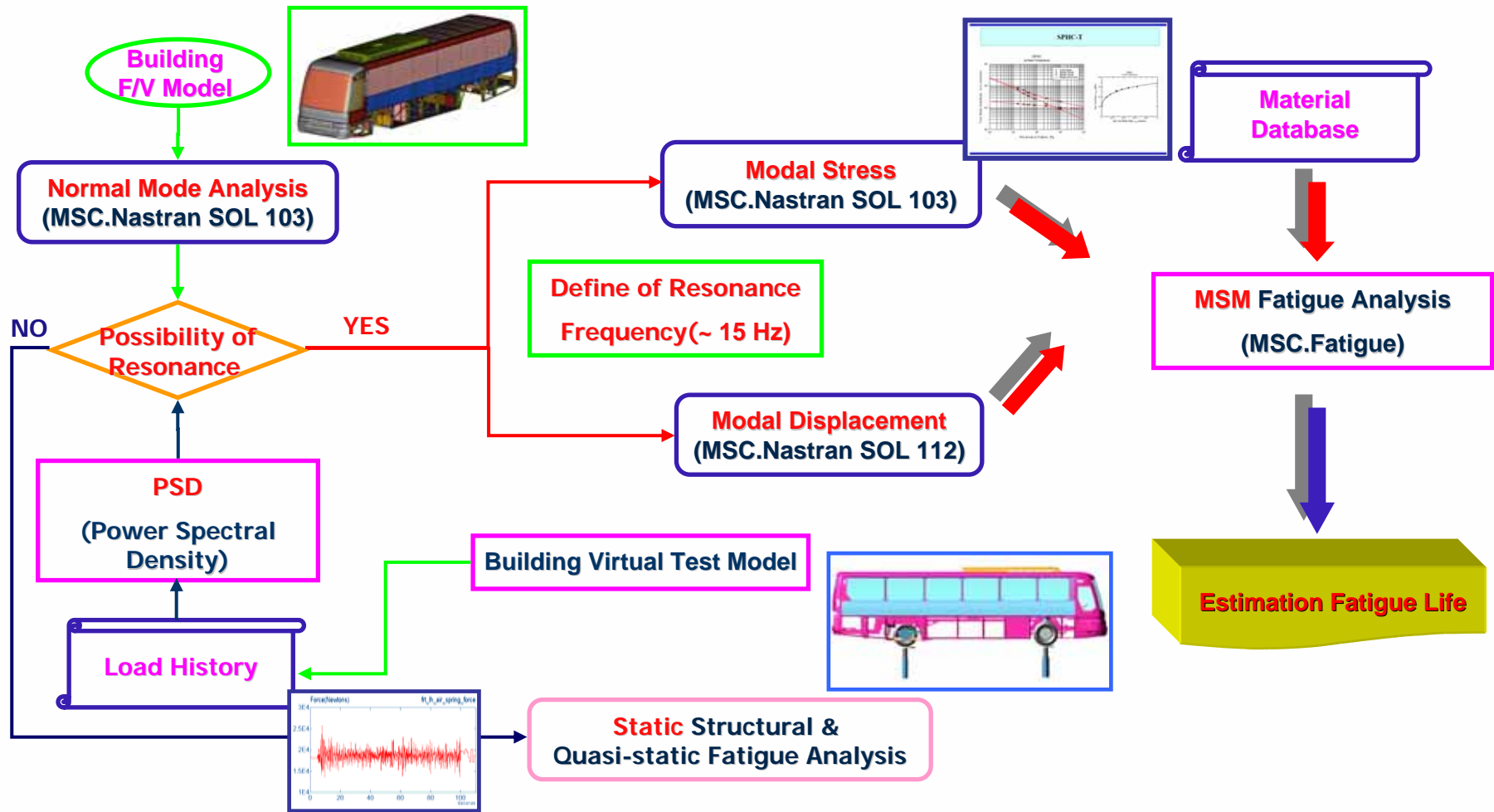
Stress for Mode Shapes

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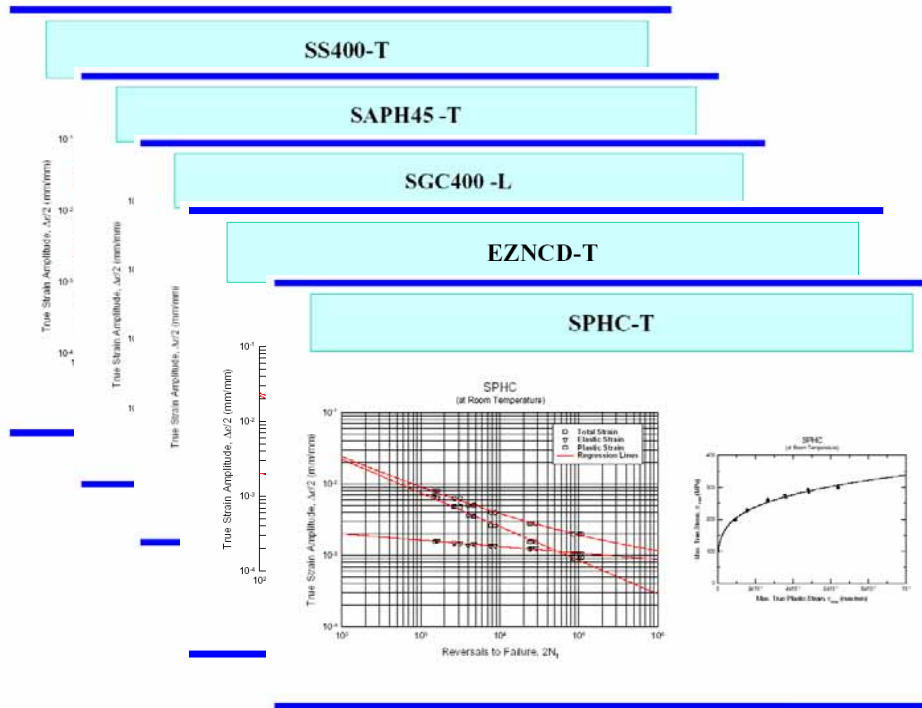




Material Properties (ϵ - n curve)

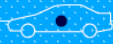


Acquisition of material properties for the bus structure

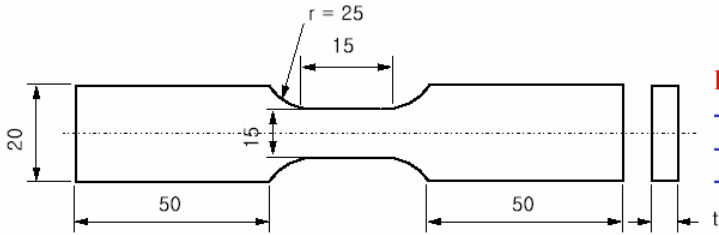


Application of a New Fatigue Test Method for the thin plate specimen

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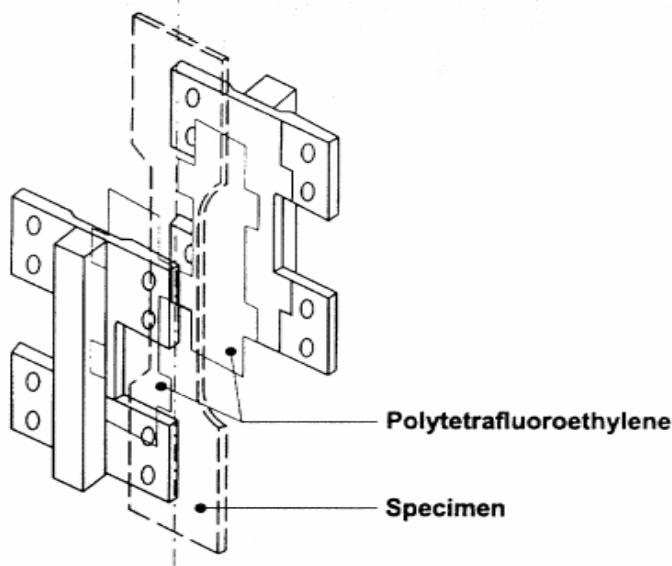


Method of Test using thin plate specimens



ISO/DIS 12106

- SGC400
- EZNCD
- SPHC



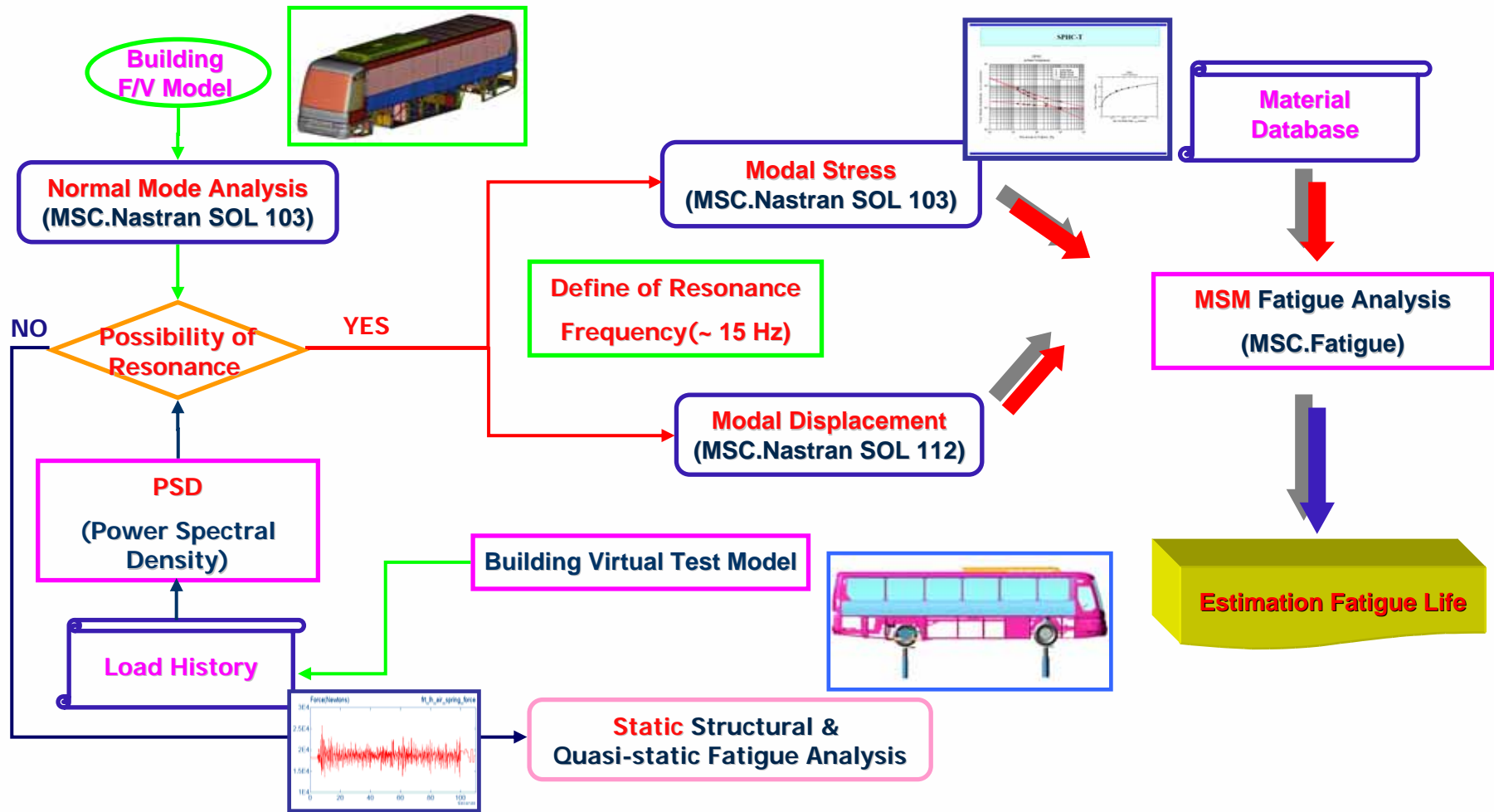
Example of Anti-buckling restraints for thin plate specimen

Anti-buckling restraints for thin plate specimen



The process of durability analysis using MSM

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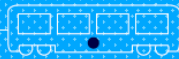




Comparison of Quasi-Static vs. MSM fatigue analysis



- **The Area Showing Discrepancy**
 - ✓ Influence of inertia for parts of large mass
 - ✓ Influence of body flexibility
- **The Area Showing Similarity**
 - ✓ The Area Influence Mass & Flexibility



Influence of inertia for large mass parts (1)



Engine Mounting Bracket : 5,150 Km



Quasi-static : 38,000 Km

MSM : 12,800 Km



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Influence of inertia for large mass parts (2)



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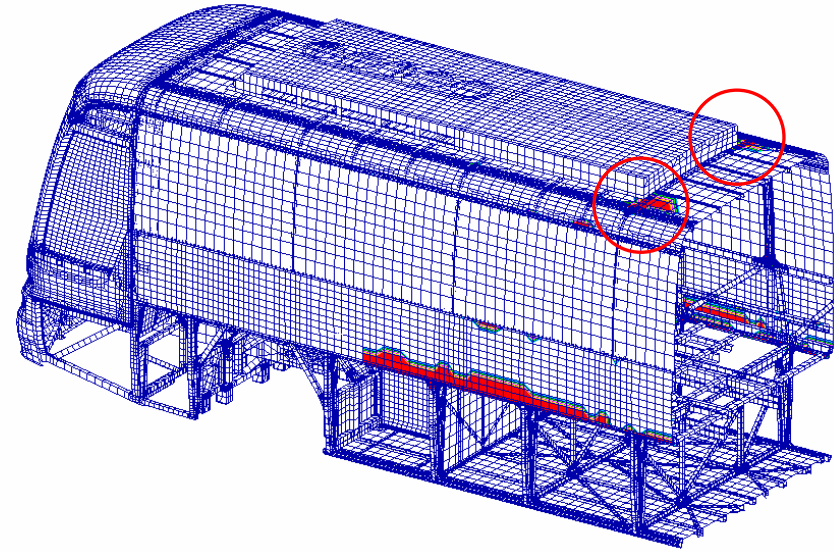
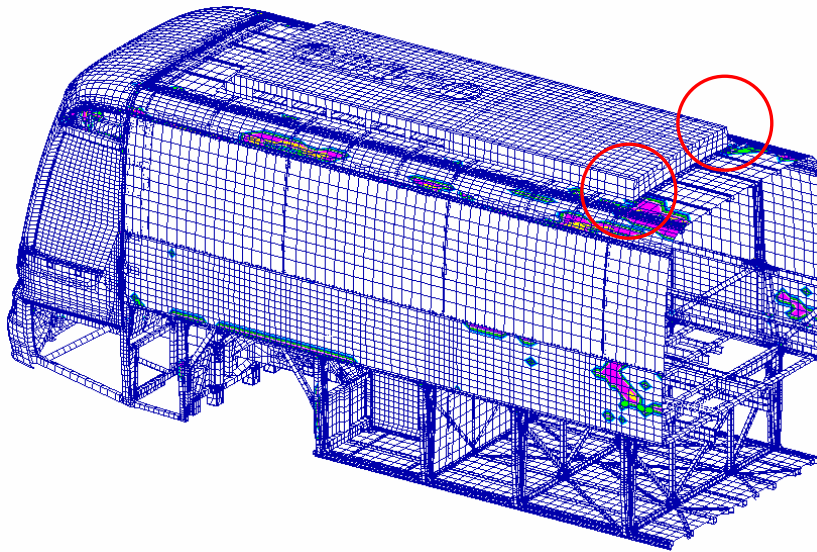
Air-con mount'g part on roof

Quasi-static

45,900 Km

MSM

2,150 Km



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Comparison of Quasi-Static vs. MSM fatigue analysis



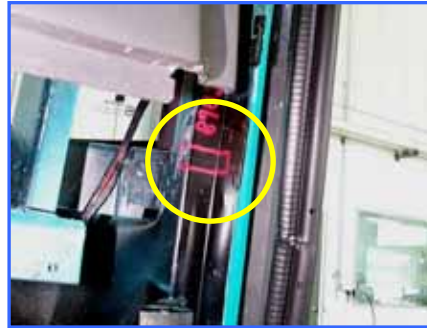
- **The Area Showing Discrepancy**
 - ✓ Influence of inertia for parts of large mass
 - ✓ Influence of body flexibility
- **The Area Showing Similarity**
 - ✓ The Area Influence Mass & Flexibility



Influence of body flexibility (1)



Lower of A-PILLAR : 8,908 Km

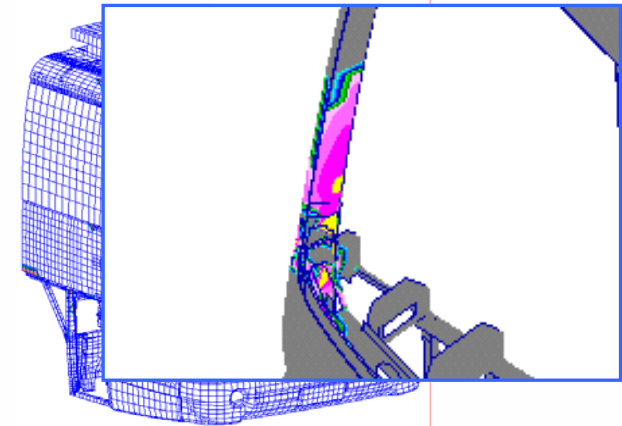
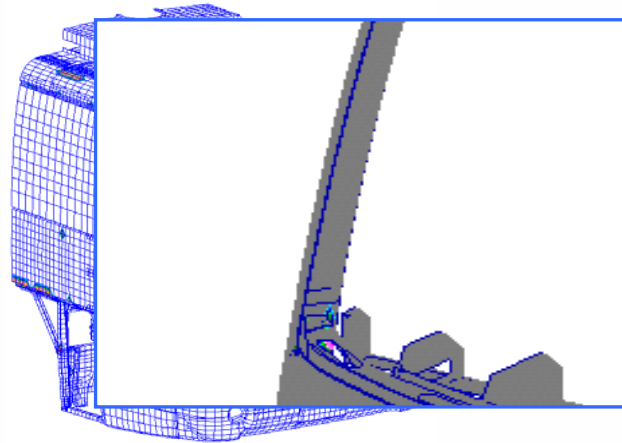


Quasi-static

81,000 Km

MSM

19,000 Km



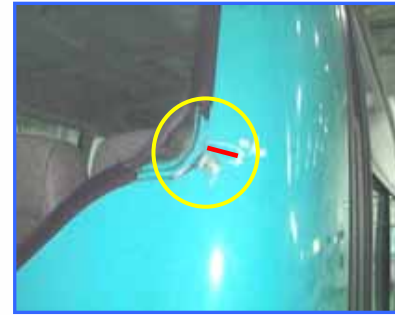
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Influence of body flexibility (2)



REAR GLASS CORNER OUTER PANEL : 5,811 Km

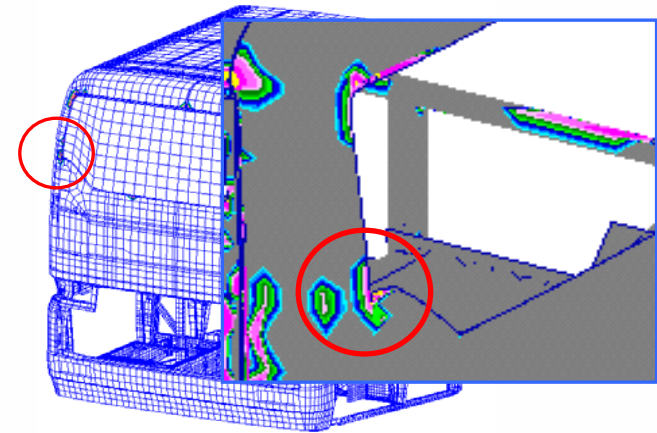
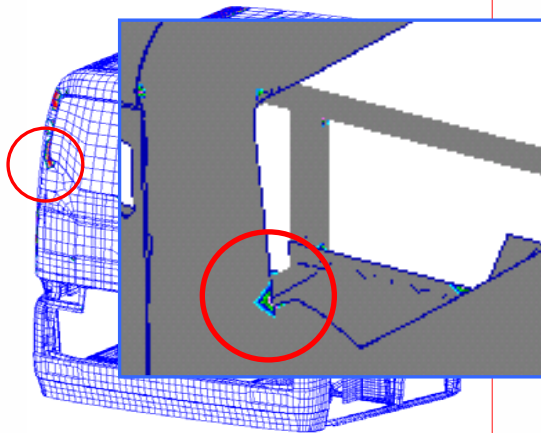


Quasi-static

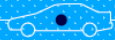
65,400 Km

MSM

19,800 Km



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Influence of body flexibility (3)



REAR GARNISH PNL : 8,260Km

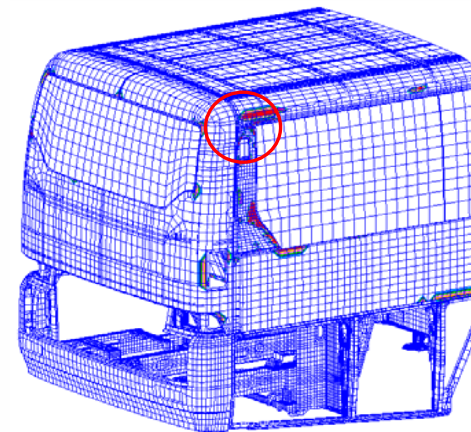
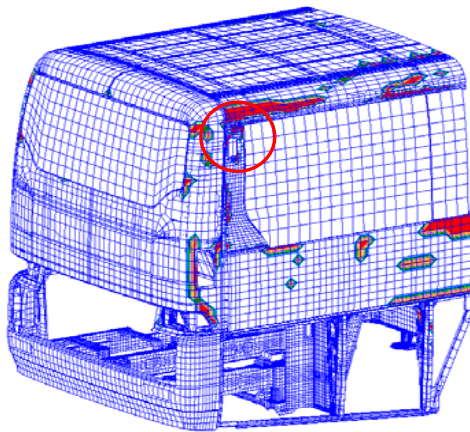


Quasi-static

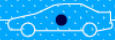
75,300 Km

MSM

23,300 Km



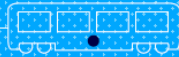
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Comparison of Quasi-Static vs. MSM fatigue analysis



- **The Area Showing Discrepancy**
 - ✓ Influence of inertia for parts of large mass
 - ✓ Influence of body flexibility
- **The Area Showing Similarity**
 - ✓ The Area Influence Mass & Flexibility



The Area Showing Similarity



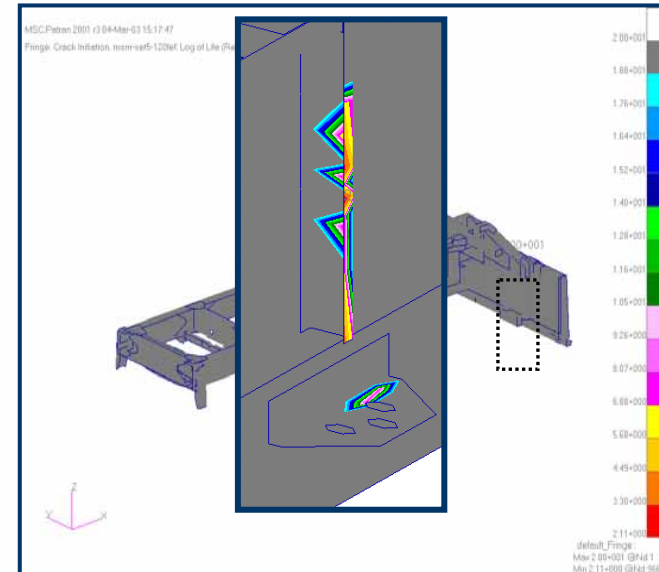
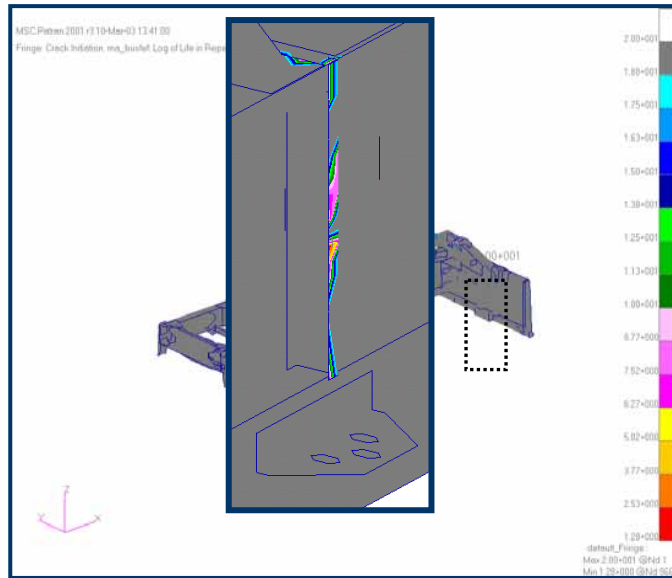
Frame : 17,000Km

Quasi-static

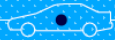
31,700 Km

MSM

29,300 Km



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Conclusion 1



- **Verified Reliability of FE model over 95% in terms of vibration characteristics of B.I.W & Trimmed body models by using the modal tests**
- **Calculated of reliable load history using Virtual Test Model**



Conclusion 2



- **Obtained a material properties by applying a new fatigue test method using thin plate specimens**
- **Understood durability analysis using MSM is more correct in the area, affected by vibrational characteristics, those are large mass area and flexible body area throughout comparison of Quasi-static and MSM durability analysis**



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Thank You